objects like enclosures and can determine interactions with the graphical image **115** locally. Force feedback used in graphical environments is described in greater detail in U.S. Pat. Nos. 5,629,594 and 5,825,308, both of which are incorporated by reference herein in their entireties.

[0131] Sensor signals used by microprocessor **970** are also reported to the computer **150**, which updates a host application program and outputs force control signals as appropriate. For example, if the user moves force feedback mouse **800**, the computer **150** receives position and/or other signals indicating this movement or manipulation of the user object **130** and can move a displayed graphical image **115** in response. In an alternate embodiment, no local microprocessor is included in the haptic interface **140**, and the computer **150** directly controls and processes all signals to and from the electronic interface **810** and mechanical interface **830**.

[0132] A local clock **975** can be coupled to the microprocessor **970** to provide timing data, similar to system clock **960** of the computer **150**; the timing data might be required, for example, to compute forces output by actuators **910** (e.g., forces dependent on calculated velocities or other time dependent factors). In alternate embodiments using the USB communication interface, timing data for microprocessor **970** can be retrieved from the USB interface. Local memory **980**, such as RAM and/or ROM, may be coupled to microprocessor **970** in to store instructions for microprocessor **970** and store temporary and other data. Microprocessor **970** may also store calibration parameters in a local memory **980** such as an EEPROM. As described above, link or member lengths or manufacturing variations and/or variations in coil winding or magnet strength can be stored. If analog sensors are used, adjustments to compensate for sensor variations can be included, e.g. implemented as a look up table for sensor variation over the user object workspace. Memory **980** may be used to store the state of the force feedback device, including a reference position, current control mode or configuration, etc.

[0133] Sensor interface **985** may optionally be included in electronic interface **810** to convert sensor signals to signals that can be interpreted by the microprocessor **970** and/or the computer **150**. For example, sensor interface **985** can receive signals from a digital sensor such as an encoder and convert the signals into a digital binary number representing the position of a member or component of mechanical apparatus **830**. An analog to digital converter (ADC) in sensor interface **985** can convert a received analog signal to a digital signal for microprocessor **970** and/or the computer **150**. Such circuits, or equivalent circuits, are well known to those skilled in the art. Alternately, microprocessor **970** can perform these interface functions without the need for a separate sensor interface **985**. Alternatively, sensor signals from the sensors **905** can be provided directly to the computer **150**, bypassing microprocessor **970** and sensor interface **985**. Other types of interface circuitry can also be used.

[0134] Actuator interface **990** can be optionally connected between the actuators **910** and microprocessor **970**. Actuator interface **990** converts signals from microprocessor **970** into signals appropriate to drive the actuators. Actuator interface **990** can include power amplifiers, switches, digital to analog controllers (DACs), and other components. Such interfaces are well known to those skilled in the art. In alternate embodiments, actuator interface **970** circuitry can be provided within microprocessor **970** or in the actuators **910**.

[0135] In the described embodiment, power is supplied to the actuators **910** and any other components (as required) by the USB. Since the electromagnetic actuators of the described embodiment have a limited physical range and need only output, for example, about 3 ounces of force to create realistic force sensations on the user, very little power is needed. A large power supply thus need not be included in interface system or as an external power adapter. For example, one way to draw additional power from the USB is to the haptic interface **140** to appear as more than one peripheral to the computer **150**; for example, each provided degree of freedom of force feedback mouse **800** can be configured as a different peripheral and receive its own allocation of power. Alternatively, power from the USB can be stored and regulated and thus used when needed to drive actuators **910**. For example, power can be stored over time and then immediately dissipated to provide a jolt force to the user object **130**. A battery or a capacitor circuit, for example, can store energy and discharge or dissipate the energy when power is required by the system and/or when enough power has been stored. Alternatively, a power supply **995** can optionally be coupled to actuator interface **990** and/or actuators **910** to provide electrical power. Power supply **995** can be included within the housing of the haptic interface device **140**, or can be provided as a separate component, for example, connected by an electrical power cord. The power storage embodiment described above, using a battery or capacitor circuit, can also be used in non-USB embodiments to allow a smaller power supply **995** to be used.

[0136] Mechanical interface **830** is coupled to the electronic interface **810** and may include sensors **905**, actuators **910**, and linkage **835**. These components are described in detail above. Sensors **905** sense the position, motion, and/or other characteristics of force feedback mouse **800** along one or more degrees of freedom and provide signals to microprocessor **970** including information representative of those characteristics. Typically, a sensor **905** is provided for each degree of freedom along which force feedback mouse **800** can be moved, or, a single compound sensor can be used for multiple degrees of freedom. Example of sensors suitable for embodiments described herein are optical encoders, as described above. Linear optical encoders may similarly sense the change in position of force feedback mouse **800** along a linear degree of freedom. Alternatively, analog sensors such as potentiometers can be used. It is also possible to use non-contact sensors at different positions relative to mechanical interface **830**, such as Hall effect magnetic sensors for detecting magnetic fields from objects, or an optical sensor such as a lateral effect photo diode having an emitter/detector pair. In addition, velocity sensors (e.g., tachometers) for measuring velocity of force feedback mouse **800** and/or acceleration sensors (e.g., accelerometers) for measuring acceleration of force feedback mouse **800** can be used. Furthermore, either relative or absolute sensors can be employed.

[0137] Actuators **910** transmit forces to force feedback mouse **800** in one or more directions along one or more degrees of freedom in response to signals output by microprocessor **970** and/or the computer **150**, i.e., they are "computer controlled." Typically, an actuator **910** is provided for each degree of freedom along which forces are desired to be